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TITLE

FUSION WELDS, VARIOUS CONFIGURATION IN 4130 STEEL SHEET AND BAR, THE MATERIAL HEAT TREATED AFTER WELDING. - INVESTIGATION OF STRENGTHS.

REPORT NO.	DATE	MODEL NO.
MSD-1164	4-29-55	MX-883 & X-7A

SUBMITTED UNDER (CONTRACT, SPEC., ETC.)

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REPORT NO. MSD-1164

DATED April 29, 1955

LOCKHEED AIRCRAFT CORPORATION

MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

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MODEL MX-883 & X-7A REFERENCE EWA-1076 SN/121

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NO. PAGES 11 NO. PICTURES 8

NO. DRAWINGS 1

REVISIONS

DATE	REV. BY	PAGES AFFECTED	REMARKS

FORM MSD 402

1.0 REFERENCES:

1.1 IDC, J. A. Johnson to C. R. Bumstead dated February 10, 1955.

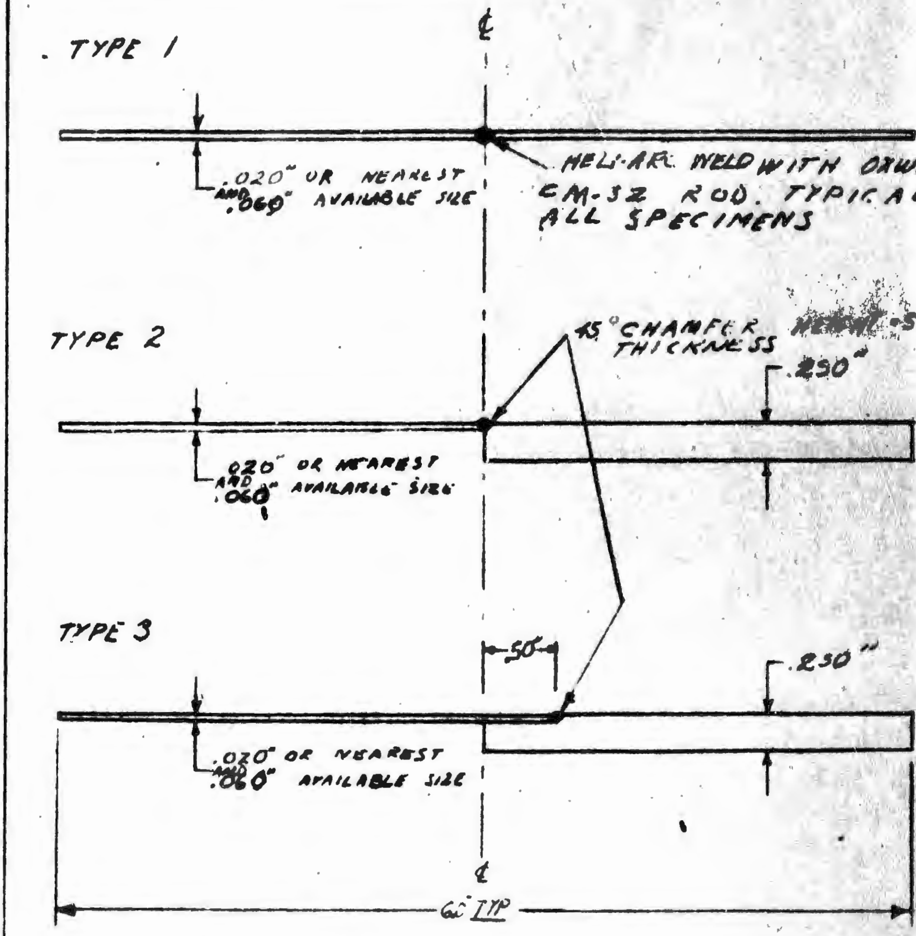
1.2 ANVO, K. M. Fisher to R. R. Schmidt dated March 21, 1955.

1.3 Interoffice Notebook pages 182830 through 182836 (issued to W. L. McLean)

2.0 INTRODUCTION:

2.1 The test program was requested by reference 1.1. The objectives of the program were to establish weld ultimate strength design factors for certain common weld configurations with an eye toward justifying an increase in the existing maximum weld strength design factor of 85% of the ultimate strength of the parent material. The specimens were manufactured in the configurations, heat-treats and quantities shown on Figure 1. The tests were performed in the Baldwin-Tate-Emery SR-4 Universal Testing Machine in the Engineering Test Department Laboratory on April 14, 15 and 18, 1955 under EWA 3-4880-1076 (Dept. 74-24 Service Number 121)

	NAME	DATE	LOCKHEED AIRCRAFT CORPORATION MISSILE SYSTEMS DIVISION	Page	TEMP	PERM.
Prepared	[illegible]	2-7-55				2
Checked	McLEAN	4-25-55	TITLE WELDING SPECIMENS	Model	MX883 X-7A	
Approved			FIGURE No 1	Report No.	MSD-1164	



MATERIALS

TYPE 1 SHEET 4130 STEEL HEAT-TREAT 150-170 & 180-200

TYPE 2 & 3 SHEET 4130 STEEL HEAT-TREAT 150-170 & 180-200

TYPE 2 & 3 BAR SAME HEAT-TREAT AS SHEET 4130 STEEL

NOTE: FABRICATE SPECIMENS IN 7" WIDE SECTIONS, CUT 5 1" WIDE COUPONS FROM CENTRAL PORTION AFTER HEAT TREATMENT. SPECIAL CARE WILL BE REQUIRED IN CUTTING TO PREVENT HEATING

3.0 PROCEDURE:

3.1 The three types of test specimens are shown on Figures 2, 3, and 4. The specimens were set up in the SR-4 Universal Testing Machine as shown in Figure 5. Serrated wedge-type grips were utilized to secure the coupons. Specially made, extra thick grips were used on one side of the crosshead grip to accommodate the offset construction of the Type II and Type III specimens. The coupon was loaded in tension until failure and the maximum load recorded. All coupons had been Rockwell Hardness tested to determine heat-treat, but these values, especially those for the 0.020 material, were not considered to be sufficiently accurate. Consequently, for all specimens where weld failure occurred in the sheet, the remaining tab was re-tested to determine the true heat-treat.

3.2 Typically, the weld failures occurred in the fusion zone and/or the refined zone of the parent material. For Types II and III, this occurred in the thin sheet in almost every case although several failures occurred in the 0.250 plate and several other failures transgressed the weld. Typical weld failures for each of the three specimen Types are shown in Figures 6, 7, and 8. Failures of the parent sheet material were of a typical brittle material shear-tension type as illustrated on Figure 9.

Fig. 2 Type I Coupon
Figures indicate heat-treat as determined by Rockwell Hardness Test.

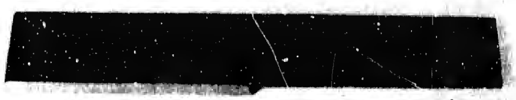


Fig. 3 Type II Coupon

Fig. 4 Type III Coupon

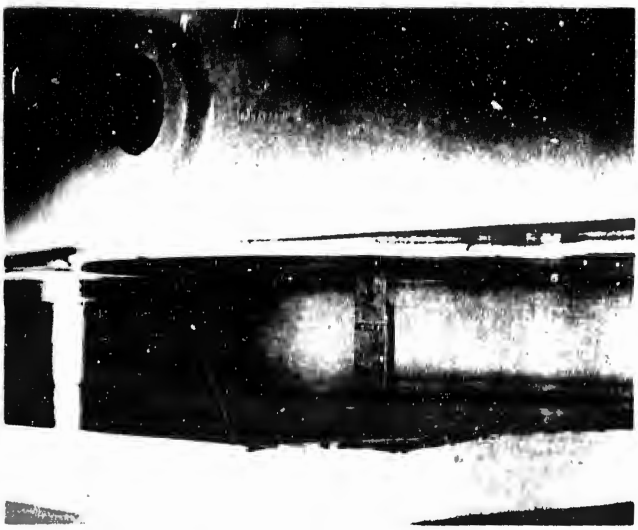


Fig. 5 Test Set-up of
Type III Coupon in SR-4
Universal Testing Machine

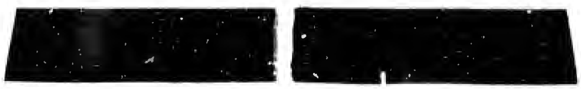


Fig. 6 Typical Weld Failure
Type I Coupon

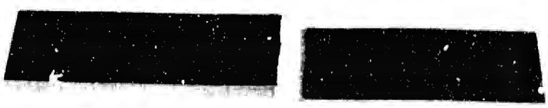


Fig. 7 Typical Weld Failure
Type II Coupon

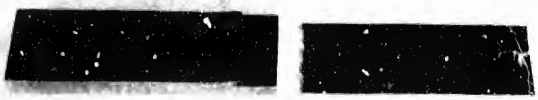


Fig. 8 Typical Weld Failure
Type III Coupon

Fig. 9 Typical Failure of
Parent Sheet Material

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4.0 DATA:

4.1 0.020 Gage Coupons

Type	Coupon No.	Width (in.)	Gage (in.)	Parent Material Ultimate Load(lb.)	Parent Material Heat Treat(psi)	Weld Ultimate Load(lb.)	Weld % Parent Material	Remarks	% Parent Material (Group Average)
I	1	1.014	0.022	3040	136	----	100		
	2	1.020	0.022	3380	151	3340	98.8		
	3	1.029	0.022	3320	147	----	100		
	4	1.013	0.022	3200	144	----	100		
	5	1.012	0.021	3400	160	3160	92.9		98.9
	6	1.031	0.019	----	----	----	----	*	
	7	0.969	0.019	2550	139	2520	98.8		
	8	1.041	0.020	2930	141	----	100		
	9	1.022	0.019	----	----	----	----	*	
	10	1.011	0.019	2820	147	----	100		
II	1	1.011	0.020	3200	158	2440	76.2	**	
	2	1.019	0.020	----	----	----	----	*	
	3	1.017	0.020	----	----	----	----	*	
	4	1.022	0.020	3460	170	3400	98.2		
	5	1.019	0.020	3480	171	3260	93.6		94.0
	6	1.031	0.020	3500	170	3450	98.6		
	7	1.006	0.020	3320	165	----	100		
	8	1.002	0.019	3280	172	3080	93.9		
	9	1.003	0.019	3120	164	3020	96.7		
III	1	0.995	0.019	2830	150	----	100		
	2	0.998	0.020	3100	155	2810	90.6		
	3	1.043	0.020	3150	151	----	100		
	4	1.016	0.020	3080	152	----	100		
	5	1.012	0.020	----	----	----	----	*	95.7
	6	1.003	0.021	2900	138	2750	94.8		
	7	1.025	0.021	3120	145	3030	97.1		
	8	1.013	0.020	3040	150	2730	89.8		
	9	1.008	0.020	3000	149	2850	95.0		
	10	1.014	0.020	3040	150	2830	93.0		

* Failure in grip.

** Defective weld.

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4.0 DATA (CONT'D)

4.2 0.060 Gage Coupons

Type	Coupon No.	Width (in.)	Gage (in.)	Parent Material Ultimate Load (lb.)	Parent Material Heat Treat (psi)	Weld Ultimate Load (lb.)	Weld % Parent Material	Remarks	% Parent Material (Group Average)
I	1	1.024	0.056	9700	169	9600	98.9		
	2	1.003	0.055					*	
	3	1.012	0.056	9600	169	9400	97.9		97.5
	4	1.021	0.055	9600	171	9200	95.8		
	5	1.020	0.056					*	
	6	1.038	0.056					*	
	7	1.018	0.055					*	
	8	1.023	0.057					*	
II	1	1.001	0.058	11000	189	10100	91.8		
	2	1.004	0.057	11200	197	7800	69.6	**	
	3	1.003	0.055	10900	198	----	100		87.2
	4	1.003	0.057	11000	192	8400	76.3	**	
	5	1.001	0.056	10900	194	10700	98.1		
	6	0.989	0.055	9500	175	9000	94.7		
	7	0.996	0.055	9500	173	9300	97.8		
	8	0.997	0.055	9500	173	----	100		95.5
	9	0.998	0.054	9400	175	8650	92.0		
	10	1.006	0.055	----	----	8500	----	***	
	11	0.998	0.054	9200	171	8540	92.8		
III	1	1.001	0.056	10600	189	9500	89.6		
	2	1.013	0.056	10600	187	9750	92.0		
	3	1.007	0.056	10800	192	9700	89.8		88.9
	4	1.003	0.056	10800	192	8700	80.6		
	5	0.991	0.055	11100	204	10200	92.0		
	6	0.991	0.054	----	----	8300	----	***	
	7	0.999	0.053	----	----	8200	----	***	
	8	1.011	0.054	----	----	8200	----	***	
	9	0.991	0.053	9000	171	8700	96.7		94.6
	10	0.995	0.054	9300	173	8600	92.5		

* Warped coupon.

** Defective weld.

*** Failure in 0.250 plate.

5.0 CONCLUSIONS:

5.1 At the outset, it should be emphasized that a test program of this type cannot be looked upon as conclusive in itself, but rather as only an indication of the results that might be expected from a more comprehensive program. The quantity of test coupons of each type scheduled to be tested was too small to give quantitative results. Moreover, the number of coupons actually satisfactorily tested was significantly less than scheduled because of warped specimens and specimens which failed in the grips.

5.2 The test results are tabulated on pages 8 and 9. Considering the 0.020 specimens, it is seen that, in many instances, the strength of the weld was greater than that of the parent material. Designating the relative strengths in these cases as 100%, the minimum average relative strength of weld to parent material is 94% for Type II specimens. This suggests that a higher design weld factor might be in order in this gage range. No correlation is possible between heat-treats and relative strengths due to the fact that heat-treats vary considerably and do not fall into the desired limits. Apparently, normal heat-treating procedure is unsatisfactory in this thickness range. One possible improvement in this connection would be to heat-treat in an inert atmosphere to reduce the effect of surface decarburization.

5.3 For the 0.060 gage specimens, the heat-treat ranges were generally satisfactory. For this gage, however, various difficulties prevent positive correlation of the heat-treats and specimen types with weld strengths. Of Type I specimens, only three specimens out of eight gave satisfactory results, the remaining five being badly warped (see below). In the 180-200,000 psi range of Type II, two specimens having defective welds (see below) brought down the average strength considerably. In Type III, 150-170,000 psi range, three of the five specimens failed through the end of 0.250 plate and therefore contributed no useful information. Only the Type II, 150-170,000 psi range, and Type III, 180-200,000 psi range tests consisted of a sufficient number of perfect coupons to give reliable results. The relative strength values of 95.5% and 88.9% respectively suggest two possibilities: (1) an inverse relationship exists between heat-treats and weld strengths or (2) the Type II weld is stronger than the Type III weld. Additional testing would be required to resolve these alternatives.

5.4 Low weld strength factors in three cases [Type II - 0.020 (1) and 0.060 (2)] were found to be due to blow-holes in the welds. Since all coupons of a particular type were cut from a single weld assembly, these defects were obviously not attributable

5.0 CONCLUSIONS: (CONTD)

5.4 to isolated faulty welds, but rather to conditions which might crop up at any point in otherwise perfect weld. Consequently, in a comprehensive test program for purposes of establishing weld design factors, these coupons would have to be considered as representing the strengths to be expected in a certain percentage of normal welds. It is therefore suggested that improvement of our present welding techniques and quality controls is in order if higher weld design factors are to be realized.

5.5 As mentioned above, two difficulties, warped coupons and breakage of the coupons in the grips, were responsible for reduction of the number of usable specimens. Coupons in both the 0.020 and 0.060 gages of the Type I (sheet-to-sheet) specimens were badly warped, apparently a combination result of both welding and heat-treating. Although this warpage had no apparent effect on the strength of the 0.020 specimens, the eccentric loading bending stresses intsoduced by this condition into the 0.060 specimens resulted in premature failures. Future coupons will require holding fixtures for welding and heat treatment plus adequate tempering to prevent warpage. Breakage of the coupons in the grips was restricted to the 0.020 gage coupons. The thin gage combined with the brittleness of the steel to magnify the stress concentration effect of the grip teeth. These effects could largely be offset by deeper insertion of the specimen into the grip, but the coupons were so short that this could not be accomplished with any degree of certainty. To alleviate this problem in future tests, the use of longer specimens with flared ends is recommended.